Current research status on alternative fuels for gas turbines in JAXA

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NASA ACCESS II data workshop

Gaylord Palms Resort and Convention Center, Kissimmee FL

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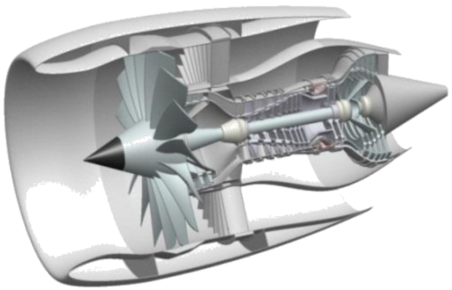
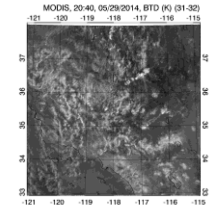
Current research on alternative fuels in JAXA

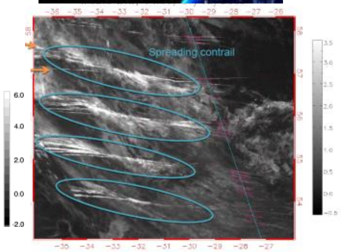
A) Collaboration with IFAR AFWG



1. A small engine test in Japan with JP8 and the HEFA bio fuel used for ACCESS II

2. Satellite image analysis of contrails of ACCESS II flight test





B) Effect of bio diesel fuels

1. 20MW gas turbine combustor rig test with diesel and 100% BDF

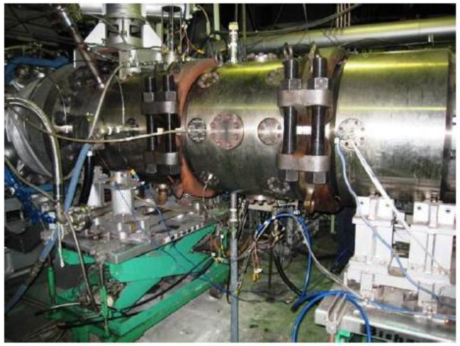


Figure 3. JAXA AP7 combustion test rig

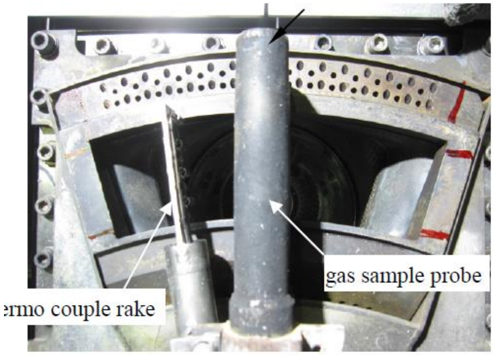


Figure 2. Downstream view of the can combustor test mod

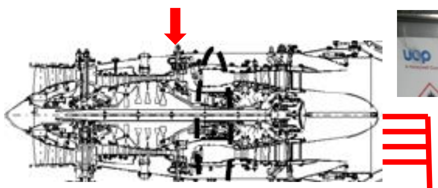
Jet engine test with conventional jet fuels and HEFA

- With special support of NASA under IFAR scheme, 800 litters of HEFA bio fuel was imported from USA to Japan.
- JP8, JP4, JP10, 100%HEFA, JP8-HEFA 50:50 blend will be tested on next month.
- Detailed analysis on engine performance and exhaust gas with special focus on PM mass and number concentrations.

2014: Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec
2015: Jan | Feb | Mar

meeting1
meeting2
meeting3
HEFA
seal tests
Engine test
Review meeting
concept, plan
plan details
measurement preparation
data analysis
fuel chemical analysis
MSS
VPR-CPC
preliminary combustion test
test data analysis
meeting4

fuel：100%HEFA, 50/50 blend, JP8, JP4, JP10



Combustor rig test
JAXA AP7
T30:500～550K
P30:500～650kPa
PLR 2～4%

MSS

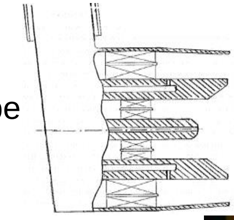
PM mass concentration
mg/m³

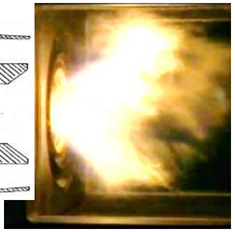
VPR-CPC

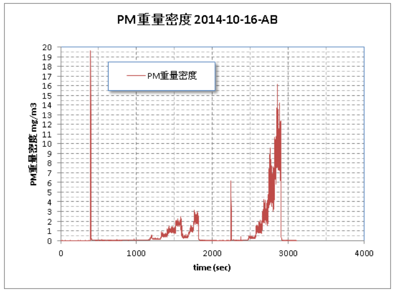
PM numbe
p/cm³

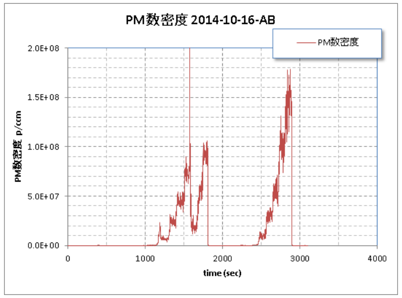
MEXA1

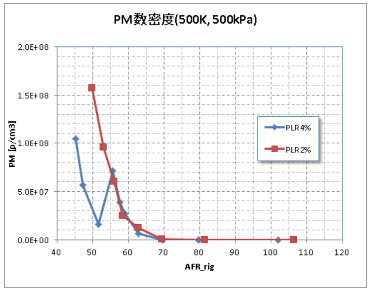
NOx, CO, THC

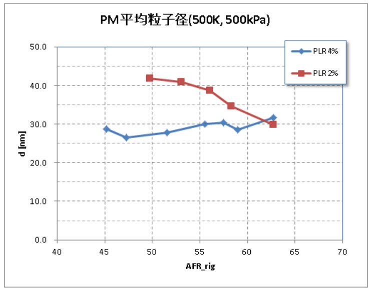








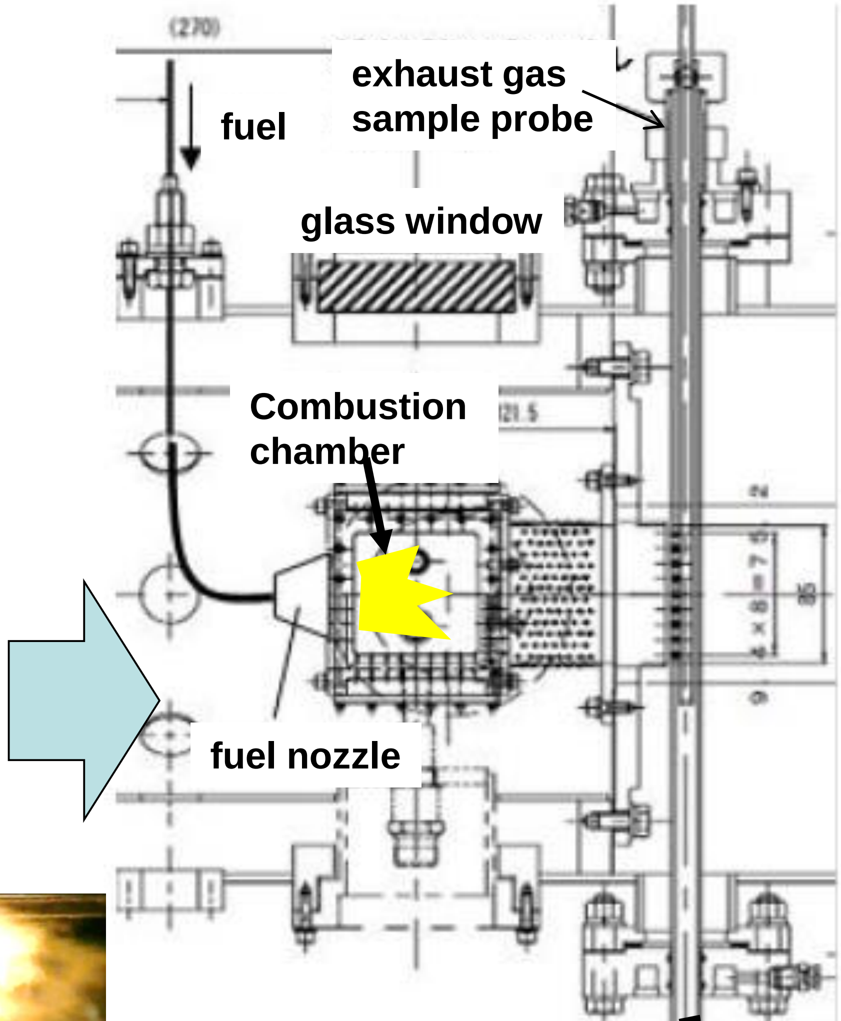


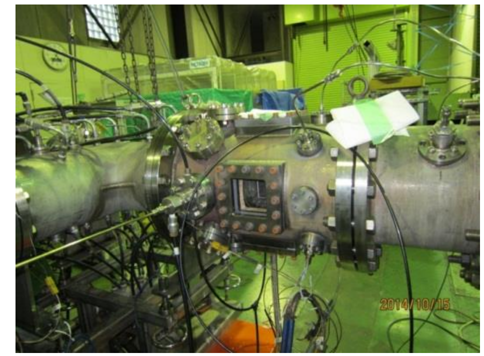


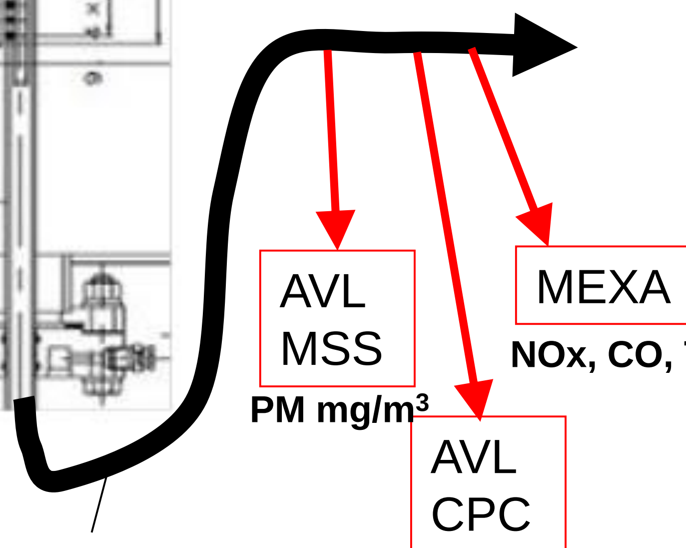
Preliminary combustor rig test at JAXA for detailed PM measurements of a gas turbine combustor

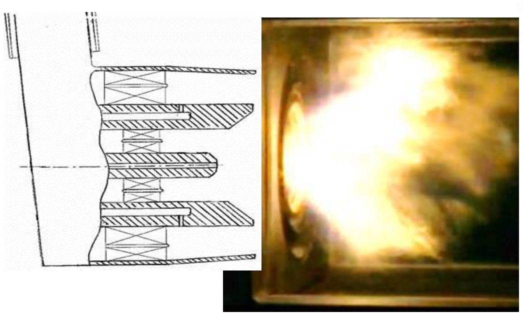
JAXA AP7 C Line combustion test rig

T30 = 500～550K
P30 = 500～650kPa
ΔP = 2～4%

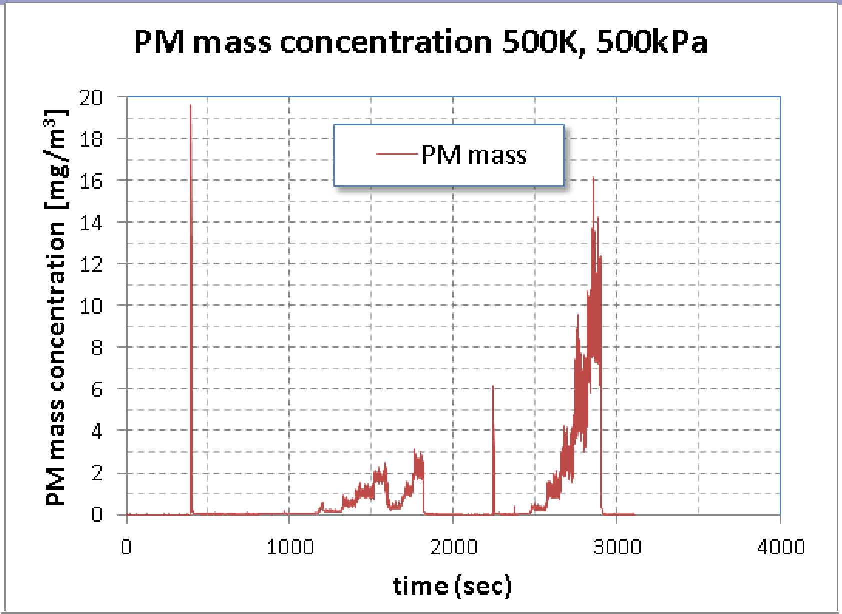


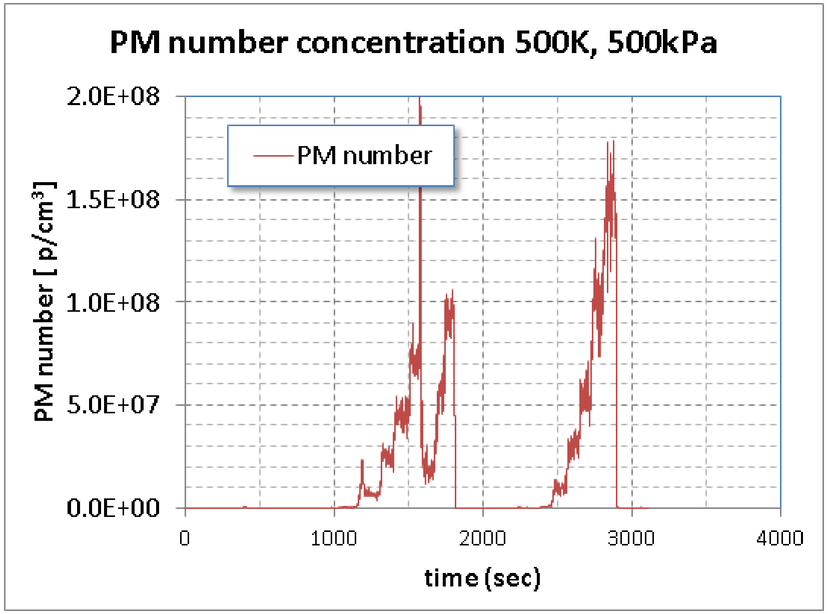


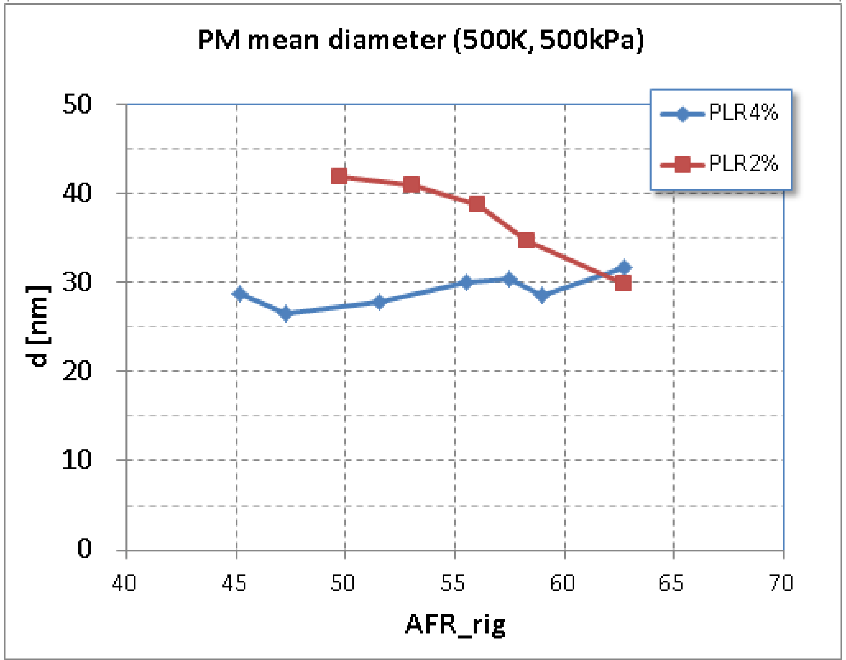




Preliminary combustor rig test







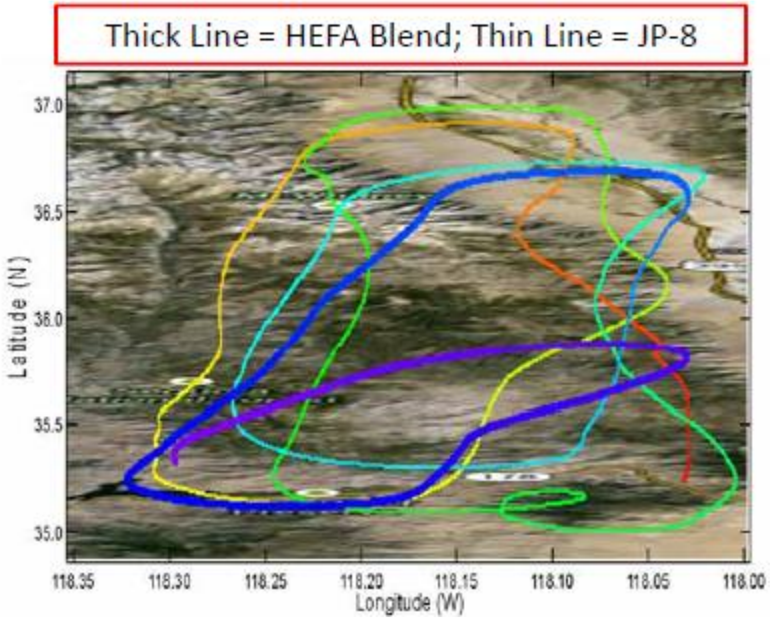
PM number concentration of gas turbine combustion turned out to be of the order of 10^7 to 10^8.

PM mean diameter turned out to be of the order of 30-50 nm.

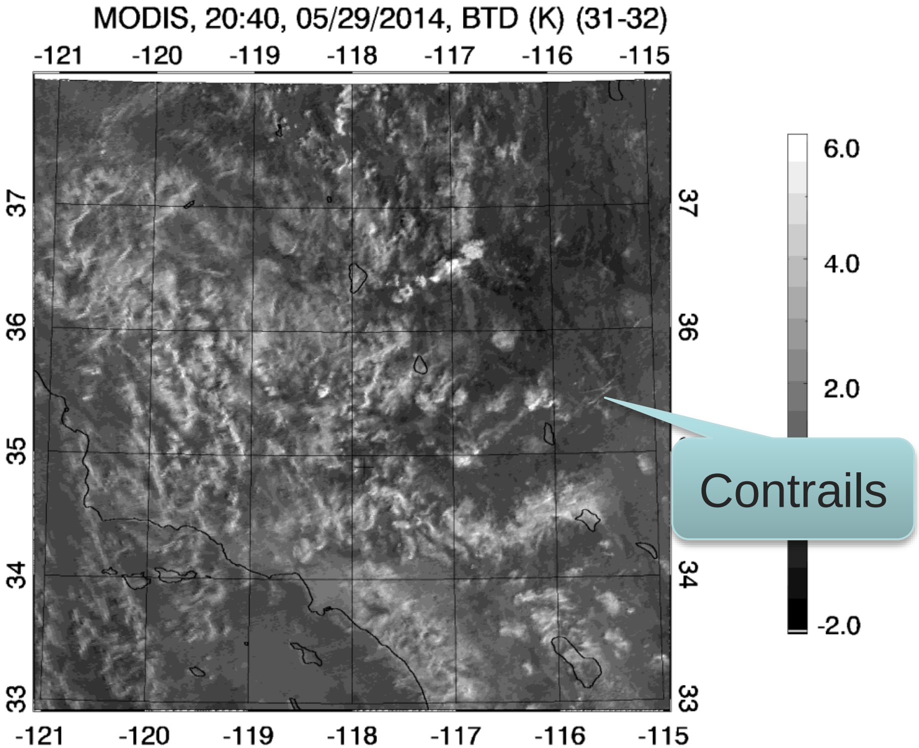
Satellite image analysis of contrails of ACCESS II

・Analysis on the Aqua/Terra satellite MODIS IR channel images to capture ACCESS II contrails and to calculate optical thickness, temperature, particle effective size based on a physical model.
（cooperation with Prof H Iwabuchi at Tohoku University)

Flight pass near Edward Air Base (USA)



5/29, IR image, AQUA MODIS camera,
UTC 20:40, brightness temp difference between No.31 and No.32



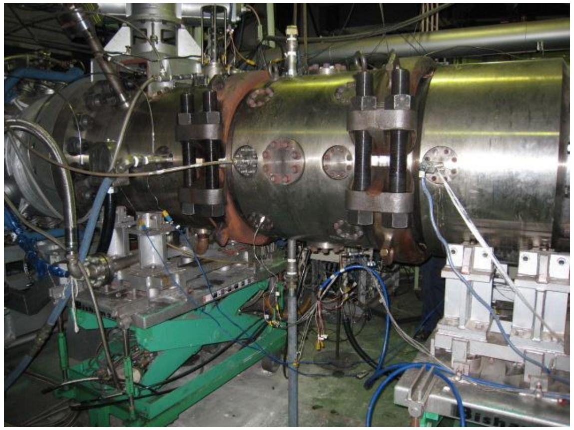
Research on bio diesel fuel

The effect of the fuel change from petroleum diesel to bio diesel fuel on the emission of a 20MW gas turbine combustor

wasted cooking oil

refined with Alkaline catalyst

Bio Diesel Fuel (BDF)



Combustion test of diesel and BDF

Japan. Endless Discovery.

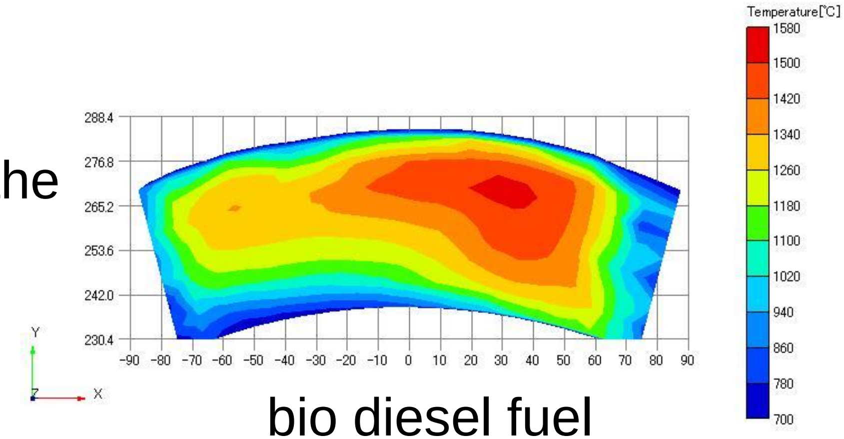
Inlet air : 1220kPa, 750K

Max outlet temp : 1800K

Fuel flow was carefully controlled so that the exit temp was nearly equal to each other to evaluate exhaust gas at the same operating condition of the GT.

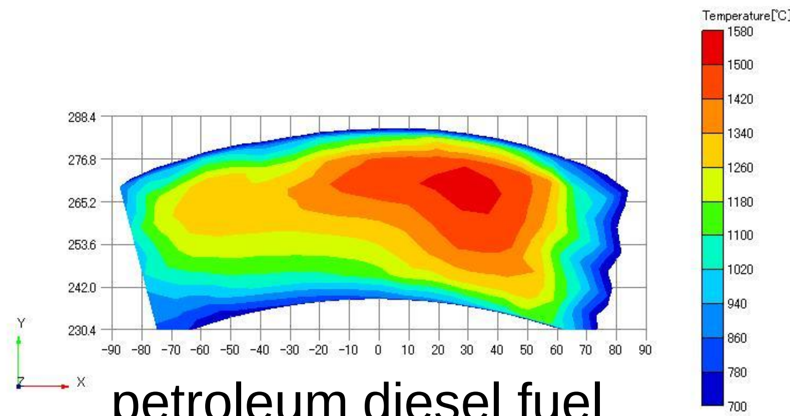
It turned out that around <u>10% more fuel is needed for BDF</u> compared with diesel (mass base) for the same output of the gas turbine because of the lower heat release of BDF per unit mass

exit temperature distribution



bio diesel fuel

fuel / air ratio = 0.0222

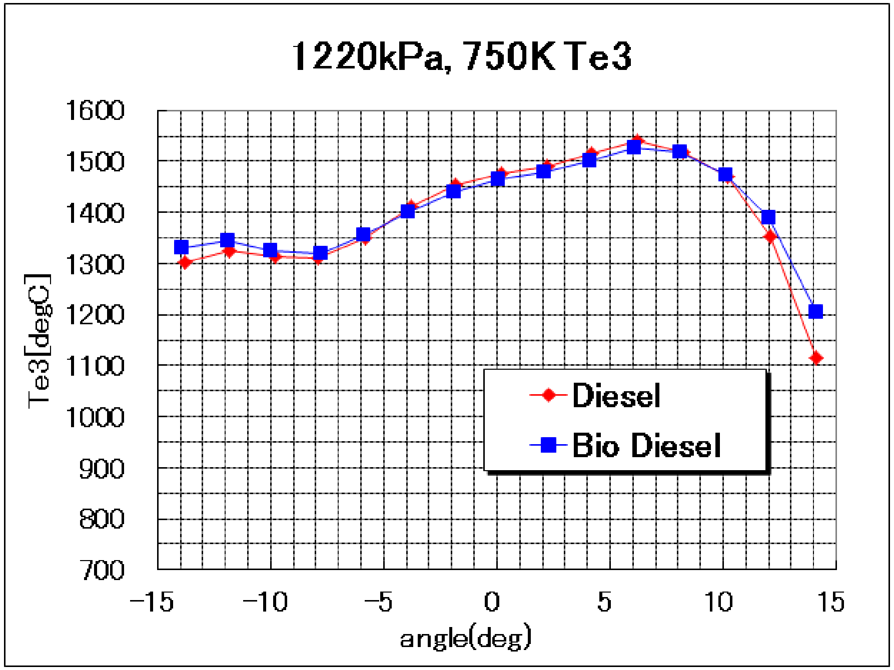


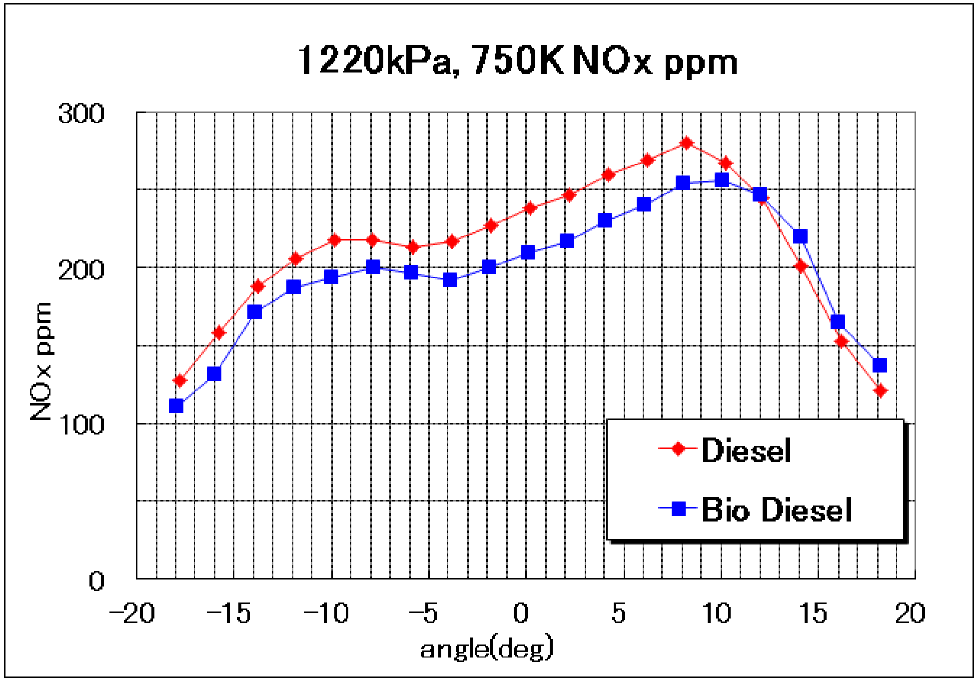
petroleum diesel fuel

fuel / air ratio = 0.0201

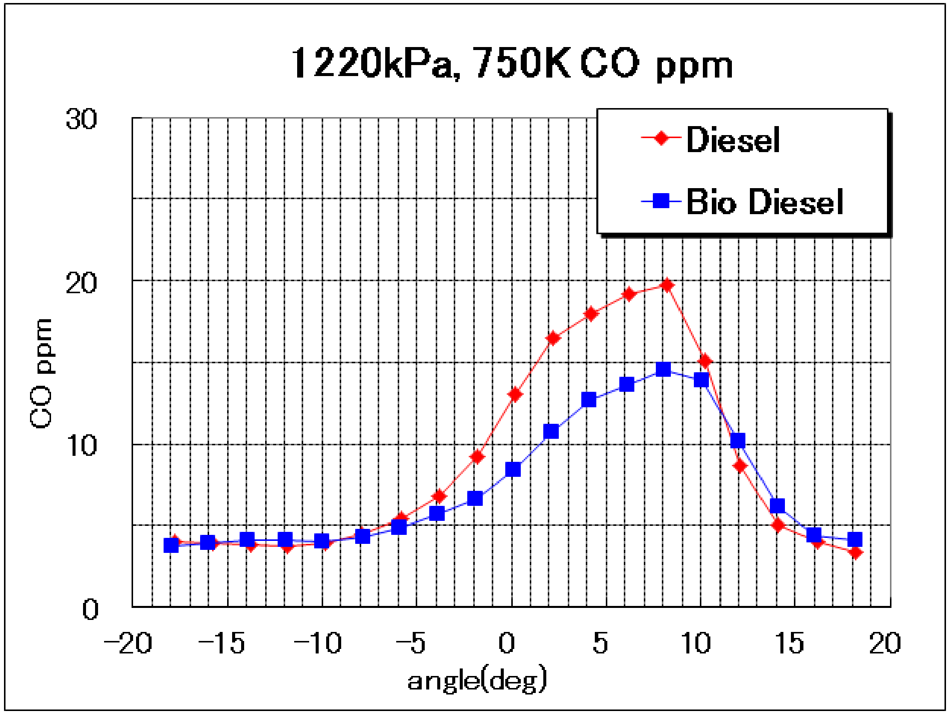
Combustion test of diesel and BDF

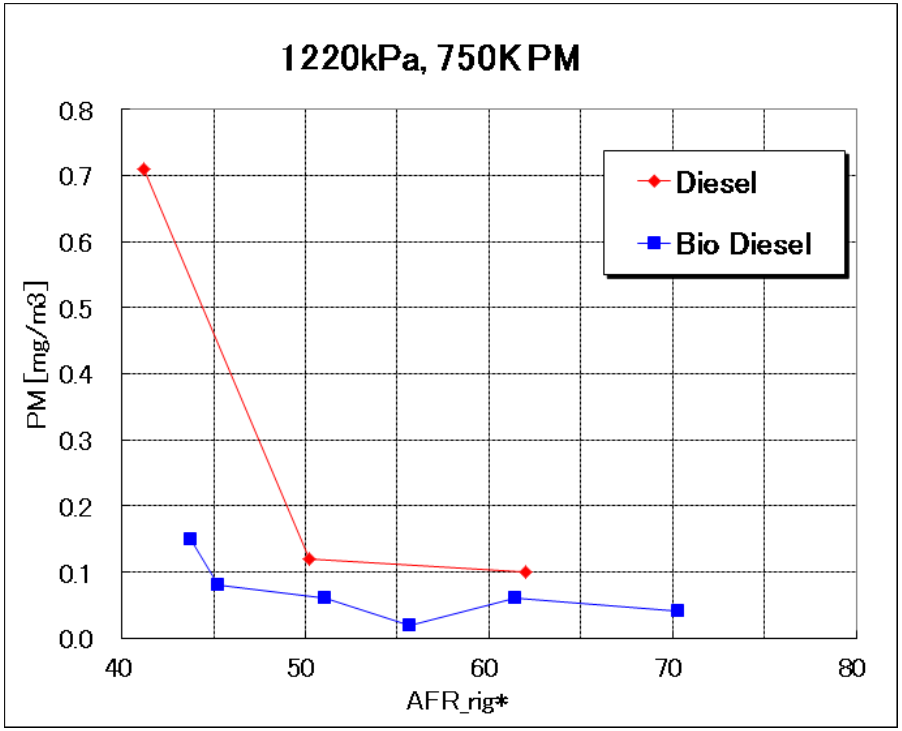
Japan. Endless Discovery.





Combustion test of diesel and BDF





Combustion test of diesel and BDF

Combustion test of BDF and diesel showed that:

・Around 10% additional fuel needed for BDF compared with diesel at same operating condition

・Exit temperature distributions are nearly the same implying that the effect of the fuel change on turbine and overall performance is considered to be small.

・NOx, CO emission of BDF nearly equal or smaller

・PM emission of BDF smaller.

Ignition, seal, degradation of performance with long time use, ... should be considered,
but BDF turned out to be a promising alternative of diesel for gas turbines

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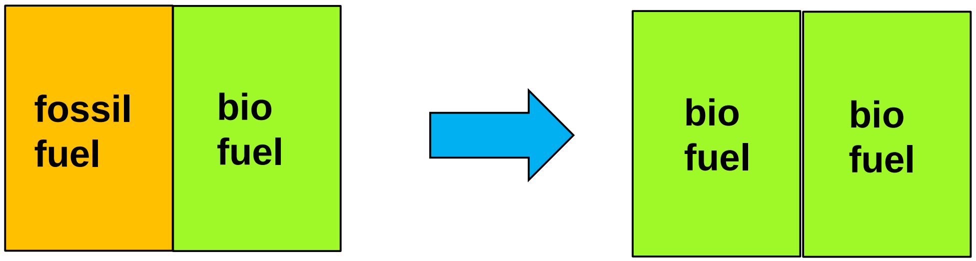
1. Current research on alternative fuels in JAXA
   A) Researches in collaboration with IFAR Alternative fuels working group
   B) Research on the effect of the fuel change from petroleum diesel to a bio diesel fuel
2. Some research proposals for future collaboration in IFAR/AFWG

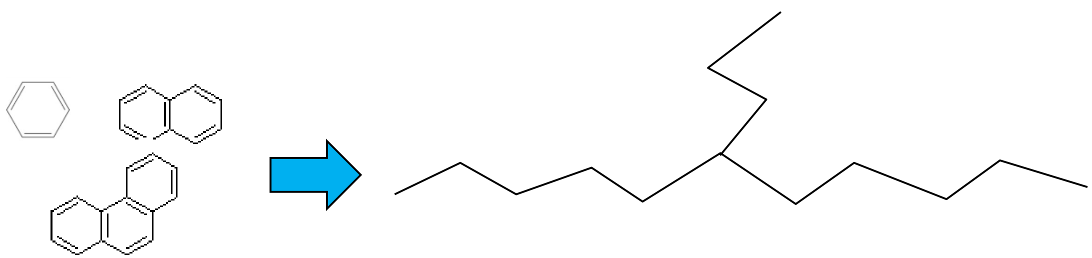
Future plan / proposals for cooperative activities IFAR AFWG

1. Activities toward the possibility for 100% bio fuel commercial flight
   (research on the ideal chemical component of commercial bio fuel)



What limits the percentage of bio fuel?

- fuel seal issues, density, freezing point, ...
- Ensuing a lowest percentage of aromatics may solve the above issues, but still causes PM emission.

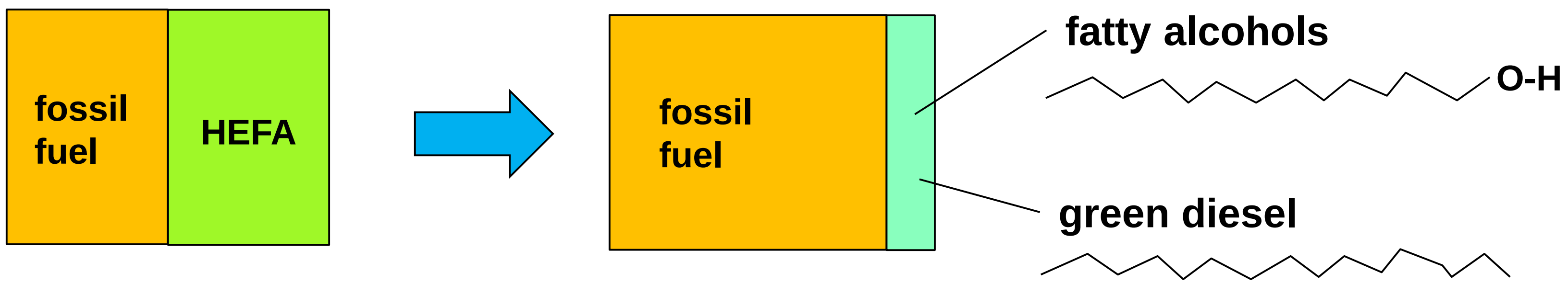


isoparaffines

Aromatics

Future plan / proposals for cooperative activities IFAR AFWG

2. Activities toward the possibility for containing some fuel with different chemical (research on broaden the source of aviation jet fuel)



- Containing some small amount of alcohols might have favorable effect on emissions.

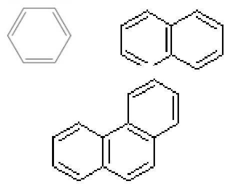
- Promoting the increase in the use of bio-fuel in aviation through broadening the range of aviation fuel specification, though additional proactive engine endurance tests might be needed to eliminate failures and to assure the airworthiness.

3. Sharing any failures/incidents related to the use of alternative fuel obtained in the world.

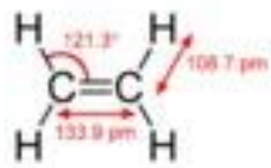
4. leading innovation to increase the production of aviation alternative fuel.

Future plan / proposals for cooperative activities IFAR AFWG

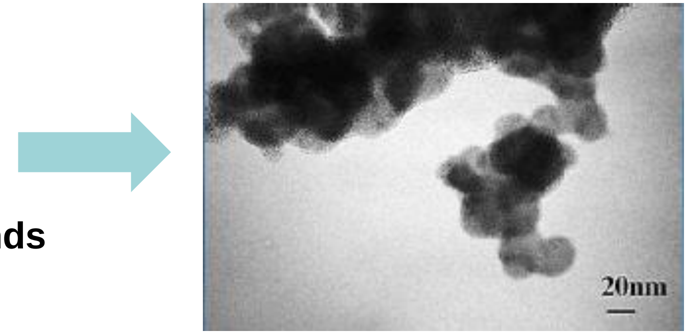
5. Basic research on the mechanism of PM reduction on the use of alternative fuels



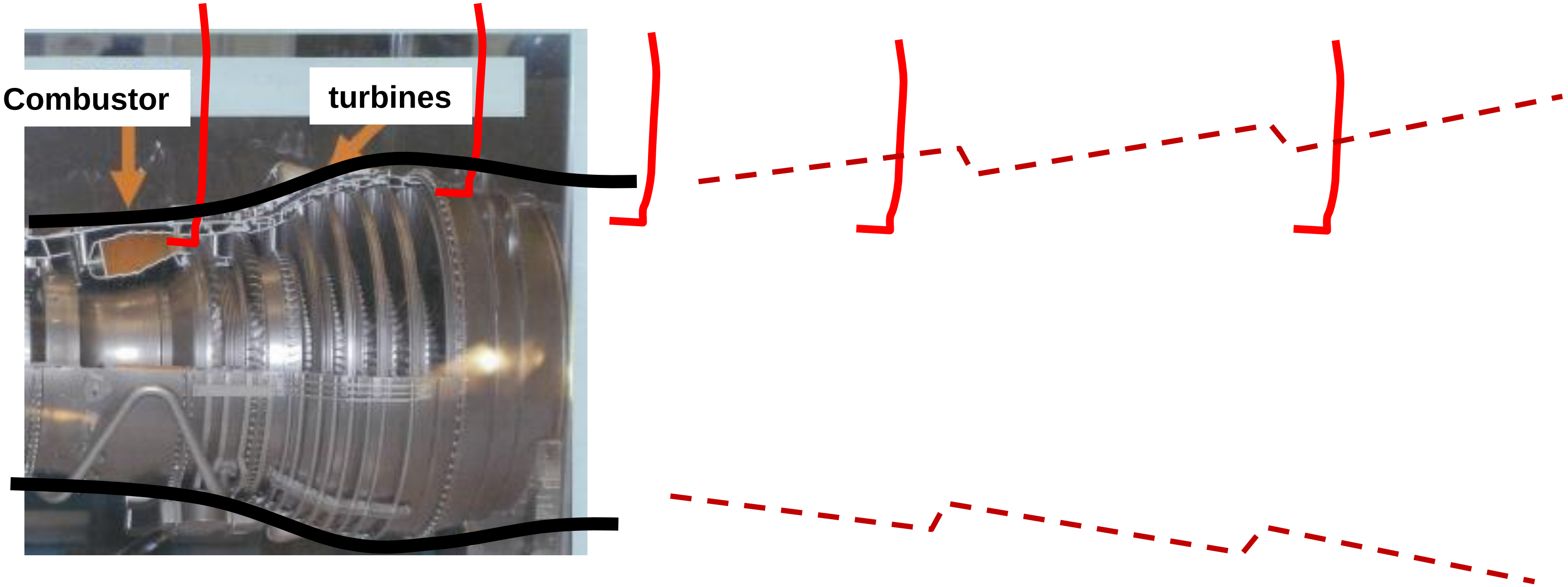
Aromatics



number of double bonds
(iodine value)



6. Measurement of PM mass/number concentration at each station of a jet engine, such as exit of combustor, HP/LP turbines, nozzles, outside atmosphere to investigate the PM diversion and bonding during its passing through these components Simulation/modeling are also important.



Summary

1. Current research status on alternative fuels in JAXA
   A) Collaboration with IFAR AFWG
      - Engine test in Japan with JP8 and the HEFA bio fuel used for ACCESS II in February
      - Satellite image analysis of ACCESS II contrails under preparation
   B) Research on the effect of the fuel change from petroleum diesel to a bio diesel fuel
      - Results showing BDF as one of promising alternative of petroleum diesel for gas turbines

2. Several ideas of future international collaboration for improving alternative fuels performance